

# **The World Bank's Role in Science and Technology**

**“International S&T Cooperation for Sustainable Development”**

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## *Abstract*

*In continued pursuit of its mandate to help countries reduce poverty and improve living standards through sustainable growth and investment in people, the World Bank has renewed, and deepened, its commitment to enhancing the contribution of science and technology to economic and social development worldwide. Through effective partnerships with other multilateral institutions, government agencies, non-governmental organizations and the private sector, the Bank aspires to apply its financial resources and extensive knowledge base towards increased efforts in the S&T sectors, which will help create the foundations of knowledge-based economies in its client countries.*

*It is important to bear in mind that the World Bank's primary interest is not in the development of new technologies, but in their ability to facilitate a wider development agenda. Hence they are usually introduced as part of a package of activities which may include policy and regulatory reform, financial or management restructuring, private sector participation and other 'non-hardware' investments which may have equal, or even greater, impact on environmentally and socially sustainable development. The Bank has been financing scientific and technological projects, and project components, since its inception. During the nineties, Bank support for S&T-related projects averaged US\$ 560 million per year.*

*Clean Energy Technologies plays an important role in the World Bank's Lending Portfolio. The Bank is involved at both the Supply Side, in which the rapid growth of gas turbine technology, particularly in combined cycles (CCGT), is the most significant example of a new, cleaner energy technology introduced into the power sectors of Bank clients in the past 10-15 years, as well as on the Demand Side, in which the Bank's efforts have been focused on facilitating the uptake of demand side efficiency technologies, through the development of energy service companies (ESCOs) and other intermediary entities. Through this mechanism for example projects have upgraded district heating systems to reduce system losses through better distribution systems, controls and management. Further the Bank has actively been involved in Fuel Switching and Improvement projects and in financing the development of Renewable Energy Sources and alternative Household Energy Supply.*

*The World Bank is currently devising a comprehensive strategy for future lending that capitalizes on the pivotal role of science and technology in the development process. The lending program for scientific and technological capacity is expected to increase, as the creation and application of knowledge play an increasingly essential part in*

*development efforts. These investments will focus on institutions, policy reform, self-enhancing financing mechanisms, and human capital development and will make effective use of state-of-the-art technologies.*

*In parallel with the development of an S&T strategy, the Bank is implementing a number of innovative actions. These include projects undertaken under the aegis of the Millennium Science Initiative (MSI). The MSI utilizes the Bank's existing lending instruments, but strongly emphasizes the need for countries to improve the performance of their science and technology systems. MSI projects are designed to stimulate national S&T systems to function according to international best practice for research funding. Through this and other actions, the Bank joins the international S&T community in placing high priority on the use of knowledge for sustainable development.*

## **Background**

The ability of a society to produce, select, adapt, commercialize, and use knowledge is critical for sustained economic growth and improved quality of life. Scientific and technological knowledge—if defined narrowly as what is produced by formal R&D systems based on Western “scientific method”—is produced by a small number of the world's richer countries,<sup>1</sup> who derive great benefit from its use. Many countries in this exclusive group enjoy the fruits of a virtuous circle, in which the concrete benefits of research help produce the wealth and public support needed to continue the investigation of science's frontiers.

Meanwhile, many of the rest of the world's nations are attempting, with varying degrees of success, to establish scientific and technological research systems that can invigorate their economies and provide solutions to their social needs, and to find ways to use existing S&T knowledge more effectively. Unfortunately, the logic of S&T research systems favors the scientifically strong becoming stronger. Countries that want to improve their S&T capacity have to make significant efforts to gain and maintain the “critical mass” of appropriate infrastructure, institutions, and human capital which function to allow benefits to start to accrue. To make matters worse, this process is often viewed as long-term and full of uncertainty, and scarce resources are always under pressure from competing needs. At the same time, science and technology continue to grow in importance as sources of critical solutions to the problems of poverty and development. Countries will find themselves looking increasingly to science and technology for answers to social and economic problems, and vastly improved S&T capacity will be needed to identify and implement these remedies.

One example, on a global scale, of the urgent need to develop S&T-based solutions to human problems is the climate change. The Earth's climate is changing because of

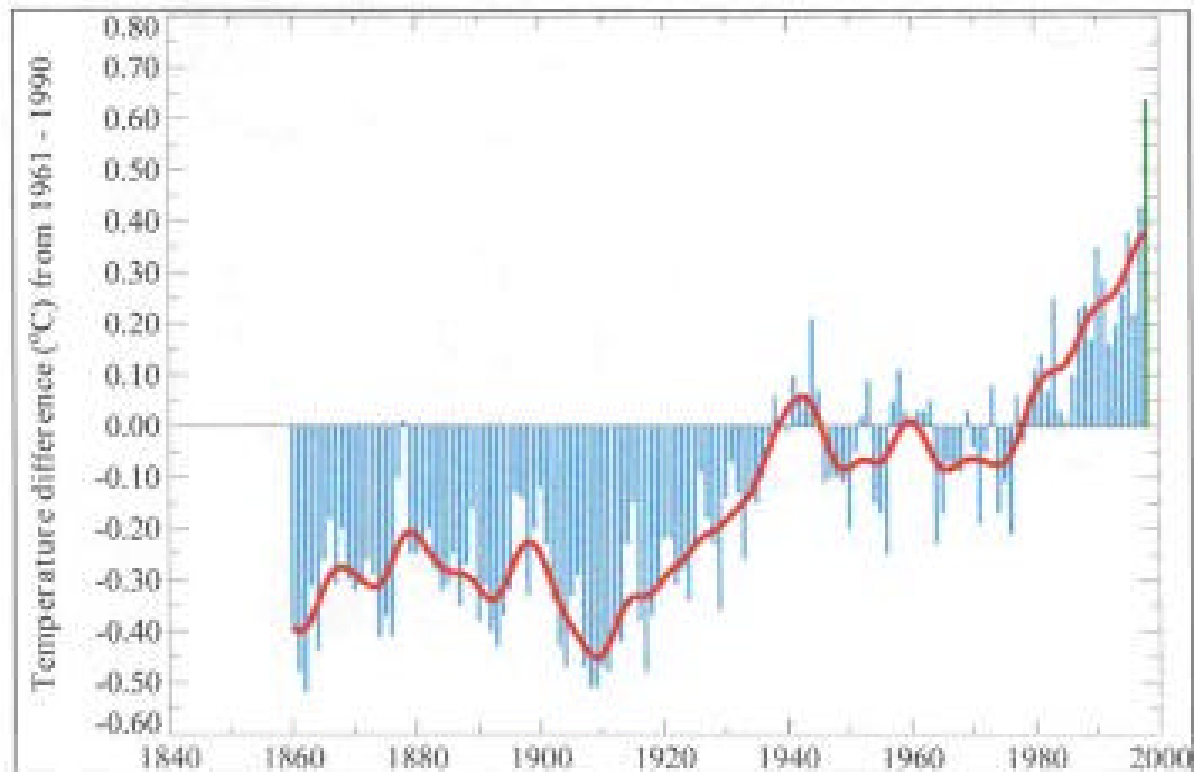
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<sup>1</sup> The best data available measure R&D in its more formal or traditional sense. The world's richest countries collect this data using criteria defined in the OECD's Frascati and Oslo Manuals. Such data show that OECD member countries accounted for 85% of investment in R&D. China, India, Brazil, and the NICs of East Asia accounted for 11%. The rest of the world's countries accounted for 4%. [UNESCO World Science Report, 1996]. It is important to emphasize, however, that R&D defined in this way is only one element of an innovation system. Other, no less important, means of innovation—especially those that take place in the productive sector or close to the end user—are more idiosyncratic and difficult to quantify.

human activity. Global scientific and technological capacity is required to counterbalance that fact. Countries at all levels of development will have to become active partners in pursuing sustainable environmental and social development.

### **Global observed temperatures<sup>2</sup>**

*Combined global land, air, and sea surface temperatures (relative to 1961/1990 average)*



Despite the difficulties, there are good reasons to expect that aspiring countries can make progress in closing the gaps that separate them from scientifically-advanced countries. First, new information and communications technologies are providing unprecedented access to existing knowledge, and are greatly diminishing the disadvantages of physical distance as a deterrent to research collaboration. Second, more is being learned about the process of innovation, and the policies and practices that make investments in S&T effective. Third, much of the international science community is by nature open to cross-border collaboration, as the progress of science depends on a culture of freely-shared basic knowledge.<sup>3</sup> The world's research community, traditionally has tremendous goodwill to help strengthen science throughout the world. Fourth, much of what countries need to accomplish in order to use scientific and technological knowledge more effectively does not involve winning Nobel prizes for research, but rather revolves

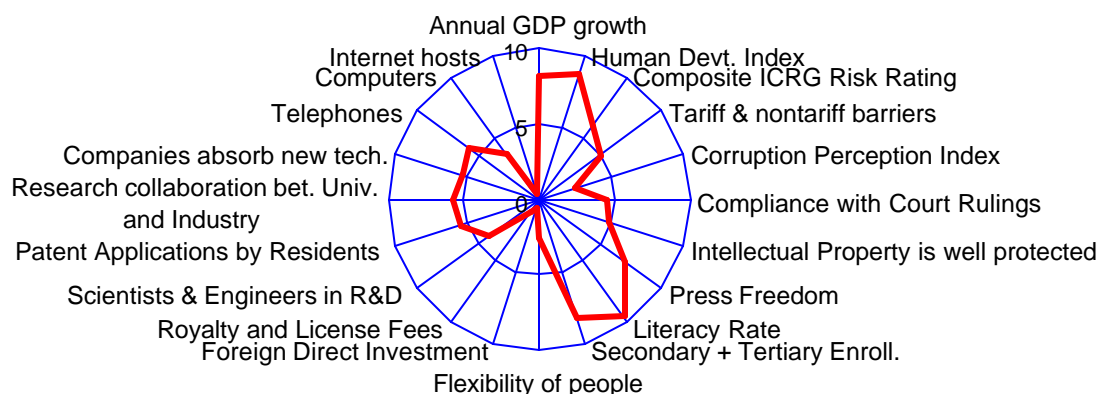
<sup>2</sup>The U.K. Meteorological Office. 1997. *Climate Change and Its Impacts: A Global Perspective*

<sup>3</sup> While this remains true in for a large number of areas of basic research, a growing number of scientific fields that produce commercially applicable knowledge are rapidly becoming more "closed" and less willing to cooperate freely for the sake of building capacity. Biotechnology is the chief example of such a field. The magnitude and consequence of this change is being studied by the Bank.

around the mundane yet essential tasks of developing well-trained people, and effective policies and institutions in S&T-related sectors.

**Knowledge is a critical determinant of economic growth and standard of living.** It is widely accepted among policymakers of the member nations of OECD, multilateral institutions and others that *knowledge is the most important factor in economic development*. The benefits to scientifically- and technologically-advanced countries are proliferating. For example, the real growth of value added in knowledge-based industries has consistently outpaced overall growth rates in all the OECD member countries for more than the past decade. Currently, investments in the intangibles that make up the knowledge base<sup>4</sup> are catching up to and exceeding investments in physical equipment. Annual Average Growth of Real Value Added in OECD Countries in the period 1985-96 was 3.5% for Knowledge Industries and 2.9% for the Business Sector Overall<sup>5</sup>.

### Korea – Score Card Indicators<sup>6</sup>



The OECD concluded that “underlying long-term growth rates in OECD economies depend on maintaining and expanding the knowledge base.”<sup>7</sup> The World Bank’s 1998/99 World Development Report (WDR) states that “Today’s most technologically advanced economies are truly knowledge-based...creating millions of knowledge-related jobs in an array of disciplines that have emerged overnight.” Developing countries are benefiting as well, but not nearly as much. At the same time, the disparities between rich and poor countries in S&T capacity, in terms of both input and output, are startling: R&D

<sup>4</sup> Defined as investments in R&D, spending on education, and investments in software.

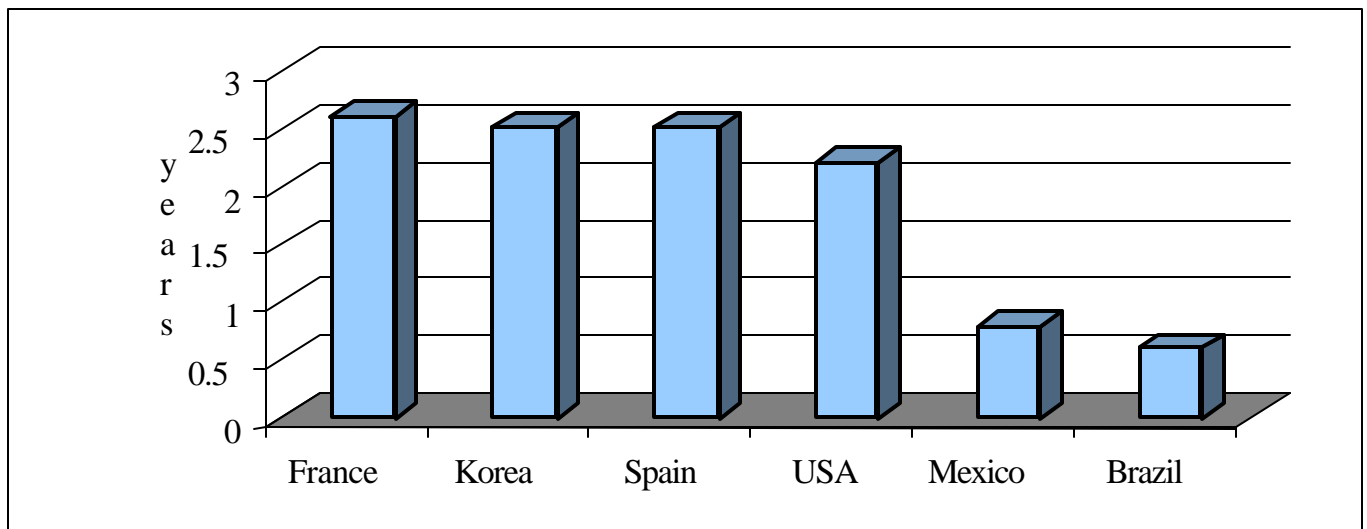
<sup>5</sup> OECD 1999, “Science, Technology and Industry Scoreboard

<sup>6</sup> Knowledge Assessment Score Card Indicators, Carl Dahlman, WBI 2000

<sup>7</sup> OECD 1998, “Technology, Productivity, and Job Creation: Best Policy Practices.” P.4.

spending by the 29 countries of the OECD in 1998 was greater than the total economic output of the world's 61 poorest countries (US\$ 500 billion versus US\$ 464 billion)<sup>8</sup>. In low-income countries, the ratio of patents filed by non-residents to those filed by residents is 690 to 1, while in high-income countries the ratio is 3.3 to 1.<sup>9</sup> In light of this situation, the 1998/99 WDR states that “the need for developing countries to increase their capacity to use knowledge cannot be overstated.” Evidence is emerging that correlates long-term economic growth with the percentage of population having tertiary education.

### Expected Years of Tertiary Education for All 17 Year-Olds



It is, of course, extremely difficult to establish direct causality among S&T capacity, technological achievement, and economic development. Nonetheless, it is likely that interesting correlations exist among progress in S&T and economic growth rates, terms of trade data, and health, nutrition, or other social indicators.

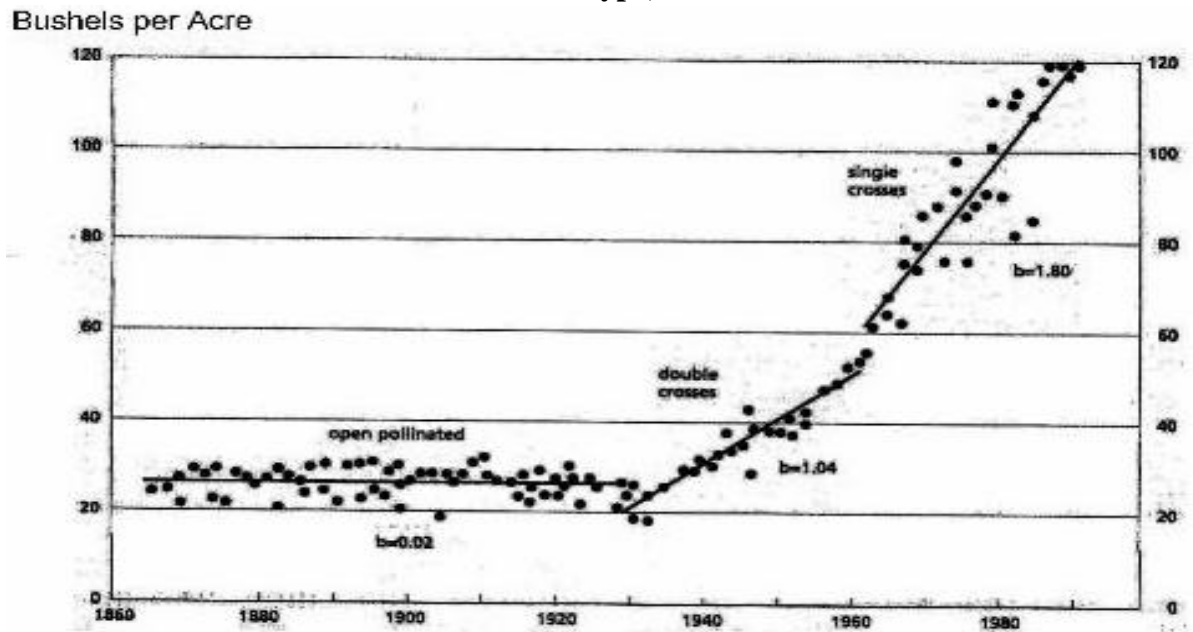
**Science and Technology Affect the Poor.** Scientific and technological progress has already brought tremendous benefits to the poor. Looked at from a longer historical perspective, it is difficult to deny the pervasive and overwhelming influence of scientific and technological progress in lifting huge numbers of people out of the ranks of poverty. Even when viewed from a shorter perspective, many of the significant recent improvements in the lives of the poor have come from the successful application of knowledge to the problems of development. Two well-known examples are the dramatic

<sup>8</sup> The low-income countries, excluding China and India: Data from World Bank's World Development Indicators 2000.

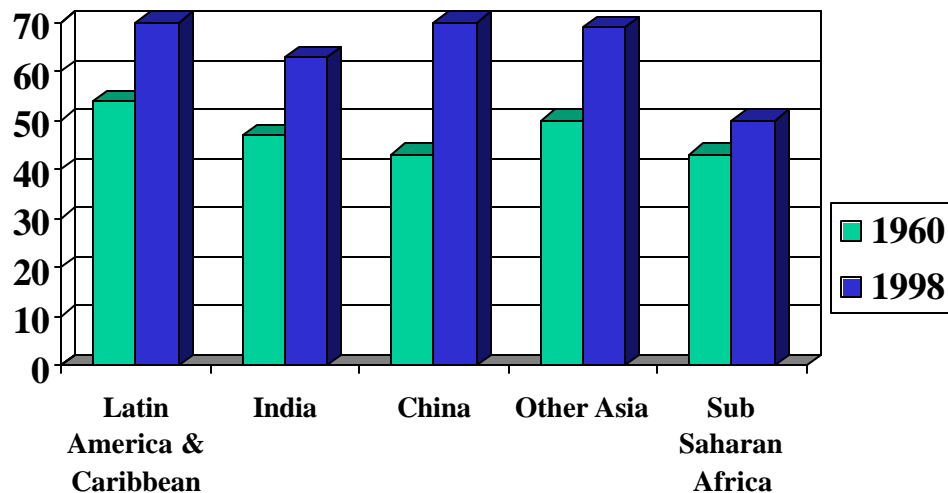
<sup>9</sup> Inventors must patent their inventions separately in each country in which they wish to have them protected. A single invention may therefore be patented in several dozen countries. Because of this, a high ratio of foreign to local patent applications indicates a low level of innovative activity among national researchers. Despite the other various factors that bear on the decision whether and where to seek patents, the ratio of foreign to domestic applications is considered a reasonably reliable indicator of national innovation effort.

rise in agricultural yields (“the green revolution”) and the control (or elimination) of diseases such as smallpox, polio, and measles.

### Corn Yield and Type, 1860-1990



### Life Expectancy at Birth in the Developing World



These two achievements alone contributed significantly to the more than fifty percent increase in life expectancy in the developing world in the period from 1950 to 1998. In addition, improved understanding of climate variation, land use change, and the dynamics of ecosystems now provides new ways to protect the current wellbeing of the poor while preserving the natural resources base on which their future income depends.

**Recognition of the Importance of S&T for Development is Not New.** Before looking at the details of the World Bank's efforts in support of science and technology, it is important to emphasize that concern for the role of S&T in the development process is not new. The goal of promoting new technologies and increased capacity to exploit scientific knowledge has been a part of the Bank's work since its beginning. Virtually every sector in which the Bank operates deals with issues involving some type of technology transfer, and usually some related building of capacity to understand and use new technologies. A partial list of areas targeted by the Bank for capacity building would include:

- Agriculture: irrigation technology, country-specific soil and crop research and extension, fertilizer use, fisheries, and others;
- Health, Nutrition and Population: drug development, vector control, habitat elimination of parasites, sanitation, water supply, reproductive health;
- Transportation/Infrastructure: civil engineering for ports, railways, and highways, shipping technologies;
- Energy: geological/geophysical surveys, hydro resource surveys, drilling technology, research on renewable energy sources;
- Information and Telecommunications: automatic exchanges, digitization, fiber optics, spread of new networking technologies;
- Urban Development: staged sanitation systems, new building materials;
- Industry/Private Sector Development: improved production techniques;
- Education: distance education, laboratory technology for educational and research, scientific literacy, critical mass of scientists and engineers.

Emphasis on improved use of knowledge, transfer of technology and information, and creation of S&T capacity has varied widely by sector. However, several sectors have made it a priority to build local capacity to either generate or utilize new knowledge for development. During the early to mid-1990's, lending in this area was concentrated:

- In Agriculture: Lending for development/improvement of National Agricultural Research Systems totals about \$250 million per year, involving 2-3 freestanding projects and up to three dozen research components within other agricultural projects in addition to \$50 million annually in grant funding for the CGIAR system;
- In Education: Close to \$150 million in annual lending for projects that improve R&D in graduate education, strengthen engineering and undergraduate training, and improve science education at secondary and primary levels;
- In Private Sector Development: Enhancing the use of knowledge in industry through matching grants, technology services for SME's, reform of public research institutes, and/or metrology, standards, testing, and quality (MSTQ) services. In addition, the Global Information and Communications Technologies Department has, over the past years, vastly expanded lending assistance for information technology and communications infrastructure.

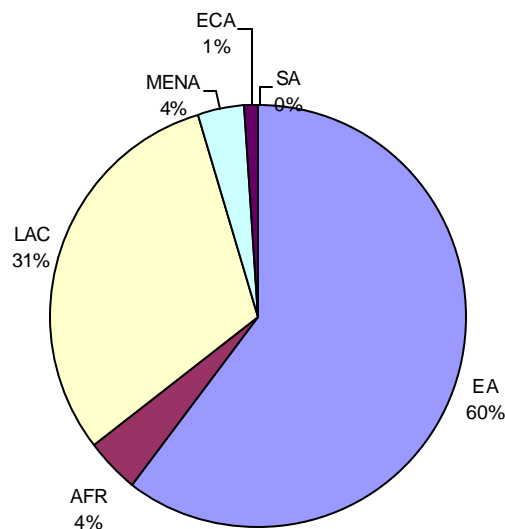
In total, about 2.5% of total Bank lending is devoted to the improvement of S&T capacity in one of these categories.<sup>10</sup> Results have varied according to case and circumstance: outside of the agricultural sector, most successes have been in large countries such as Brazil, Mexico, or China where a number of large (often sequential) projects have been implemented. Overall, however, no clearly defined strategic pattern for S&T as a whole emerges from an examination of previous experience.

## Previous World Bank Lending Experience in S&T

A review of Bank lending over the last twenty years reveals that loans to the agriculture sector account for about 50% of total S&T-related funding. Significant financing has also been provided for projects with S&T components aimed at human resource and private-sector development.

**Global Characteristics of Bank Lending for S&T.** Aggregate lending for S&T outside the agriculture sector has been examined. During fiscal years 1980-99, 59 *non-agriculture-sector* projects with specific S&T goals were approved. These projects account for US\$ 5.2 billion of the US\$ 381.8 billion (1.4%) lent by the Bank during that twenty-year period. There were on average 3 S&T projects per year, representing 1.2% of all projects. Annual average lending for S&T was US\$ 260 million. The average cost (lending plus expected counterpart contribution) of an S&T project was US\$ 181 million.

**World Bank Lending for S&T by Region, 1992-98**



Some S&T projects are broad attempts to intervene throughout the entire sector—in other

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<sup>10</sup> These figures are based on analyses of Bank Lending for S&T from 1992-98. Other analyses put lending for S&T in agriculture/rural development closer to US\$350 million per year of new commitments. The percentage figure is for overall lending, a substantial proportion of which is Adjustment Lending that has no specific sectoral focus.

words, to increase both the capacity to produce scientific knowledge and its direct use in production. This sort of comprehensive project would typically include consolidation and expansion of peer review and competitive funding as a critical means of improving the performance of the sector. Brazil's *Science and Technology Reform Support Project (PADCT III)*, for example, is devoting about US\$ 147 million (nearly half of the total project cost) to peer-reviewed, competitively awarded research grants in six priority scientific disciplines. The goal of Bank involvement is to accelerate a number of trends in effective research management. These go beyond use of peer review to include transparency, researcher autonomy, consequential monitoring and evaluation, and priority setting.

S&T projects aimed at human resource development through improvements to training systems in tertiary and secondary education often finance the provision of infrastructure and the upgrading of laboratory equipment. Kenya's *Universities Investment Project* has both a small research fund and a fund for institutional development. However, a new generation of projects to support higher education was designed during the latter half of the 1990's. These projects—for example, in Indonesia, Romania, Jordan, Argentina and Chile—target improvements in quality and efficiency through competitive funding of teaching innovation, quality enhancement and research. While at the same time supporting capacity building for policymaking, monitoring and evaluation, special attention has been paid to enhancing the financing mechanisms and to targeting sufficient resources towards the needy but talented students. Again, the idea is that the issues that surround quality of instruction and sound institutional management have a more decisive impact on the effectiveness of higher education than does the provision of physical capital and infrastructure.

Institutional grants for program development typically support the creation of new courses, upgrading of faculty skills, laboratory and equipment upgrading (for shared infrastructure or departmental labs), and support for library resources and scientific information. Overseas and domestic fellowships are common staff development tools. Collaborations among universities (local and foreign) and research institutes, and linkages with industry, are built into many of these projects, reflecting the necessity of knowledge sharing as a basis for knowledge creation.

A typical private sector development project would include significant components in any or all of three basic categories: restructuring of public R&D institutes; technology development in industry; and MSTQ. The bulk of the *Mexico: Industrial Technology Development Project* took the form of a line of credit to the country's major industrial fund, in order to strengthen its ITD financing of private industry and development of R&D capability in industry, research centers and engineering firms. Restructuring of R&D centers and metrology investments were also provided for in the project.

Some projects address R&D and technology policy concerns, but with specific focus on environmental issues. In the *China: Environmental Technical Assistance Project*, programs of both the Chinese Academy of Sciences and the National Environmental Protection Agency were supported. All supported programs sought to

increase China's ability to understand and manage environmental problems. The Chinese Ecosystem Research Network and the Biodiversity Research and Information Management Program, two initiatives of the Chinese Academy, were supported, as were waste minimization, clean production, and an environmental monitoring and assessment program of NEPA. Environmental research in the Chinese university system was also supported.

**Support for R&D in Agriculture and for National Agricultural Research Systems (NARS).** In the Bank's recent history, there has been a clear shift in focus from primarily agricultural development to other rural economy concerns, as evidenced by the increasing emphasis on such needs as rural roads and finance sustainability. Maintaining the natural resource base, for example, has become a priority for the rural sector. A similar transition toward a wider scope for the agricultural sectors impact on sustainable development has occurred within the CGIAR. The CG research agenda is now approaching balance between agricultural S&T and natural resource management.

Still, Bank support for agricultural S&T *sensu stricto* has not diminished. The Bank is the largest donor for both the agricultural sector and the agricultural research subsector.<sup>11</sup> Since 1980, support for the expansion and improvement of National Agricultural Research Systems has been an explicit priority. From 1981-96, the Bank lent \$3.9 billion for funding of agricultural research through 458 projects in 91 countries.<sup>12</sup> Of the 458, 50 projects were "free standing"—they focused exclusively on agricultural research. Support currently averages about \$200 million per year through 2-3 free standing projects and more than two dozen components in other projects. At these levels, agriculture's share of all lending for support of research is larger than that of all the other sectors combined. Lending and policy toward agricultural research have been thoroughly reviewed.<sup>13</sup> Several patterns or trends are worth noticing:

- Support for research is increasing as a percentage of all lending for at least two reasons: it remains a high priority while overall lending for agriculture is declining and resources are being shifted, in some cases, away from support of extension towards research;
- Sub-Saharan Africa is the region that receives the largest share of agricultural research lending, with this share growing in recent years (it accounted for 50% from 1993-96). This may mitigate the relative paucity of support for other types of research lending to Africa—and should be taken into consideration in formulating any S&T support strategy for the region;
- The Bank's commitment to NARS has been steady and long-term; many countries have had sequential NARS support projects, over periods extending up to 20 years;

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<sup>11</sup> All data and information in this section are from "The World Bank's Role in Strengthening National Research Systems," chapter four of Strengthening National Agricultural Research Systems: Policy Issues and Good Practice, Derek Byerlee and Gary Alex, World Bank, 1998.

<sup>12</sup> This figure represents the actual amounts devoted to the research projects/components; it has been disaggregated from the (much higher) total value of projects containing agricultural research components.

<sup>13</sup> These include the 1980 Policy Paper, research review in '83 and '87, a 1996 OED Review, a 1997 Visions and Action Paper, and several external reviews (see Ch.4 and Annex One of Byerlee and Alex, 1998).

- The Bank has made a strong and substantial commitment to develop global public goods by supporting International Agricultural Research Centers (IARCs) through, *inter alia*, its role as a sponsor of and investor in the CGIAR (to which it donates roughly US\$ 50 million per year);
- The Bank has played an important role in donor coordination. It has helped create programs and facilities such as the Special Program for African Agricultural Research (SPAAR) and the Office for Agricultural Research and Extension (ESDAR), a multi-donor forum;
- Research on natural resources management issues and related environmental concerns are increasingly seen as an integral part of sustainable agricultural policies and strategies.

*Importance of Policy and Institution-Building.* According to the analysis of Byerlee and Alex (1998), the incorporation of lessons from past experience has led to changes in lending practices, including a notable shift in priorities after 1993 toward management and policy competence, incentive systems, and accountability. The shift could be described as the adoption of a “quality agenda” that emphasizes: (a) merit and scientific rigor through the use of competitive funding, external reviews, and increased institutional linkages; (b) sustainability of funding through a variety of mechanisms including public-private interaction, cost-recovery, endowed research foundations, and farmer financing; (c) more recognition of and support for human resources training, especially as conducted at universities;<sup>14</sup> (d) continuing efforts to reform National Agricultural Research Institutes (NARIS) and the policies that affect them; and (e) increasing “knowledge-intensive” agriculture through linkages to basic research and the international knowledge base.

Trends in Institutional Issues Emphasized in Agricultural Research Projects		
Issue	Percent of 1990-93	Projects After 1993
Emphasis on institutional pluralism	50	86
Promotion of private-public interaction in R&D	12	71
Support of new funding sources	6	87
Support for competitive funding	12	86
Support for downsizing and consolidation	25	57
Involvement of farmers in research governance	38	87
Development of master plans for NARS	50	14

(Table 4.4 from Byerlee and Alex, 1998)

**Clean Energy Technologies in the World Bank’s Lending Portfolio.** The Bank's risk profile is such that it prefers to base its investments on equipment that is off the shelf. Hence it is seldom a developer or 'first adopter' of clean energy technologies. It is important to bear in mind that the Bank's primary interest is not in the development of new technologies, but in their ability to facilitate a wider development agenda. Hence

<sup>14</sup> P.63 of Byerlee and Alex notes that Bank-supported agriculture R&D projects should pay more attention to general issues of university quality and improvement, as a means to strengthening NARS. This is a potentially fruitful area of cooperation between staff in the agriculture and human developments networks.

they are usually introduced as part of a package of activities which may include policy and regulatory reform, financial or management restructuring, private sector participation and other 'non-hardware' investments which may have equal, or even greater, impact on environmentally and socially sustainable development.

*Supply Side.* The rapid growth of gas turbine technology, particularly in combined cycles (CCGT), is probably the most significant example of a new, cleaner energy technology introduced into the power sectors of Bank clients in the past 10-15 years. The twin benefits of increased energy efficiency and lower specific emissions of global and local pollutants account for its rapid uptake. Other supply side efficiency technologies include loss reduction equipment, prepayment meters (which tend to reduce consumption) and upgrading of district heating installations.

Not related to supply side efficiency but worth mentioning is the introduction of cleanup technologies, particularly those relating to meeting the requirements set out in the Bank's Pollution Abatement Handbook. Of these, flue gas desulphurization, particulate removal and low NO<sub>x</sub> burners are the most significant and are introduced for all projects with Bank financing.

*Demand Side Efficiency.* The Bank's efforts have been focused on facilitating the uptake of demand side efficiency technologies, through the development of energy service companies (ESCOs) and other intermediation entities. Thus direct involvement in technologies has been somewhat limited. Nevertheless, some projects have upgraded district heating systems to reduce system losses through better distribution systems, controls and management. Some projects have also assisted in the development of industrial cogeneration, and improved boiler and steam system efficiency. Other projects are tackling buildings energy efficiency.

*Fuel Switching and Improvement.* Substantial Bank work has been dedicated to increasing the supply of gas, which is an attractive substitute fuel – and which is a pre-requisite for fuel switching. There has also been some follow-through with projects that facilitate the corresponding hardware investments to use gas at a distributed level. There appears to be no example of a power plant repowering involving fuel switching. Extensive efforts in Eastern Europe have included fuel switching in district heating plants, principally from coal to peat, biomass and geothermal sources.

Fuel switching or reformulation has also been tackled through the energy sector to have an impact on transport. Examples include reformulating gasoline to remove lead, introduction of compressed natural gas to fuel heavy vehicles, or improvement of 2 stroke engine performance.

*Renewable Energy Sources.* The Bank has been investing in renewable energy projects for power production since at least the early 1990s. Initial investments were in geothermal and small or medium scale hydro. Subsequently, as the newer renewable energy technologies have come to commercial maturity they have been introduced. Investments in technologies using agroforestry wastes (especially bagasse), landfill gas and wind energy are now quite diverse and extensive. Both solar thermal and photovoltaics (PV) for grid connected power are now under consideration. Other modern

biomass technologies using energy crops have yet to make a significant showing. The Bank has also been active, with GEF, in promoting solar water heating for industrial and household use.

*Household Energy Supply.* Off grid electricity supply has been considerably increased using renewable energy sources. For remote mini-grids, small hydro is often the least-cost solution compared with, for example, small diesel generators. For individual systems, PV in the form of solar home systems or micro wind turbines are often the preferred energy source. Hybrid systems using part renewable energy sources, part fossil fuel have yet to be widely taken up owing to reservations about cost or reliability or both. There is renewed interest in indoor air pollution, which is primarily caused by the fuels used for cooking, and its effects on health, particularly of women and children. Two broad solutions present themselves: either adoption of improved cookstoves or fuel switching away from dung, biomass and coal, towards kerosene and gas.

Recent World Bank involvement in the area of clean technologies includes:

*Uptake of CCGTs.* In 1979, CCGTs did not enjoy their present reputation as a world beating technology – they were new in the marketplace and were unknown in the Indian power sector. IFC lent \$10 million to Ahmedabad Electric Company to invest in a CCGT. Perceived technological risks were mitigated through commercial guarantees negotiated with the equipment supplier and the location of a field service and repair facility in India.

*District Heating in Eastern Europe.* A typical project is the District Heat and Conservation Project for Estonia, which involves efficiency rehabilitation efforts in DH systems through investments in boiler conversion/replacement, changes in fuel use away from coal and major efficiency improvements in the DH systems with modern technologies and equipment. This operation, along with the Latvia Jelgava and the Ukraine Kiev projects, has had good results to date, with savings about 25% although with a wide variation.

*Efficient Industrial Boilers in China.* The Efficient Industrial Boilers Project is a stand alone GEF operation designed to improve the energy efficiency of new coal-fired small and medium-sized industrial boilers. In addition to broad support for the industrial boiler industry, GEF financing supports the procurement of technology and technical know-how from international partners for nine Chinese boiler manufactures to develop different types of more efficient industrial boiler designs. Counterpart financing (US\$68.6M) provides much of the support to put the new boiler designs into mass production for the Chinese market.

*Wind Energy Development in India.* Bank participation in the wind sector in India has catalyzed over 900MW of capacity financed by the private sector. The Bank's role has been to finance the Indian Renewable Energy Development Agency which has acted as technical and financial intermediary for the sector. Perhaps more significant than the installation of the capacity has been the creation of an industry – with over 20

manufacturers and a full range of consultants, engineers, financiers and other entities essential to build, operate and maintain wind farms.

*Improved Cookstoves in Mali.* In Mali, a project has supported the commercialization of improved charcoal stoves with considerable success. Over 86,000 stoves have been sold which have reduced wood consumption by 2.5 million tonnes and avoided the emission of over 310,000 tonnes of CO<sub>2</sub>. In addition, some 8,500 kerosene stoves have been introduced, with a further 2,000 now expected to be sold by the private sector. They have reduced woodfuel consumption by 75,000 tonnes and 103,000 tonnes CO<sub>2</sub> over the period 1997-2000. These data do not include activities which were catalyzed by the project but remain outside it.

*Compact Fluorescent Lamps in Mexico.* The ILUMEX project in Mexico was the first GEF grant funded project implemented by the Bank. The project aimed to replace about 1.7 million incandescent light bulbs with compact fluorescent lamps (CFLs) in Guadalajara and Monterrey. By project closure the target had been achieved and by six months after closure this had increased to 2.5 million CFLs. Estimated CO abatement was 764,000 tonnes. The project had a 35% IRR.

## **Towards a World Bank Strategy to Promote the Use of Science and Technology for Development**

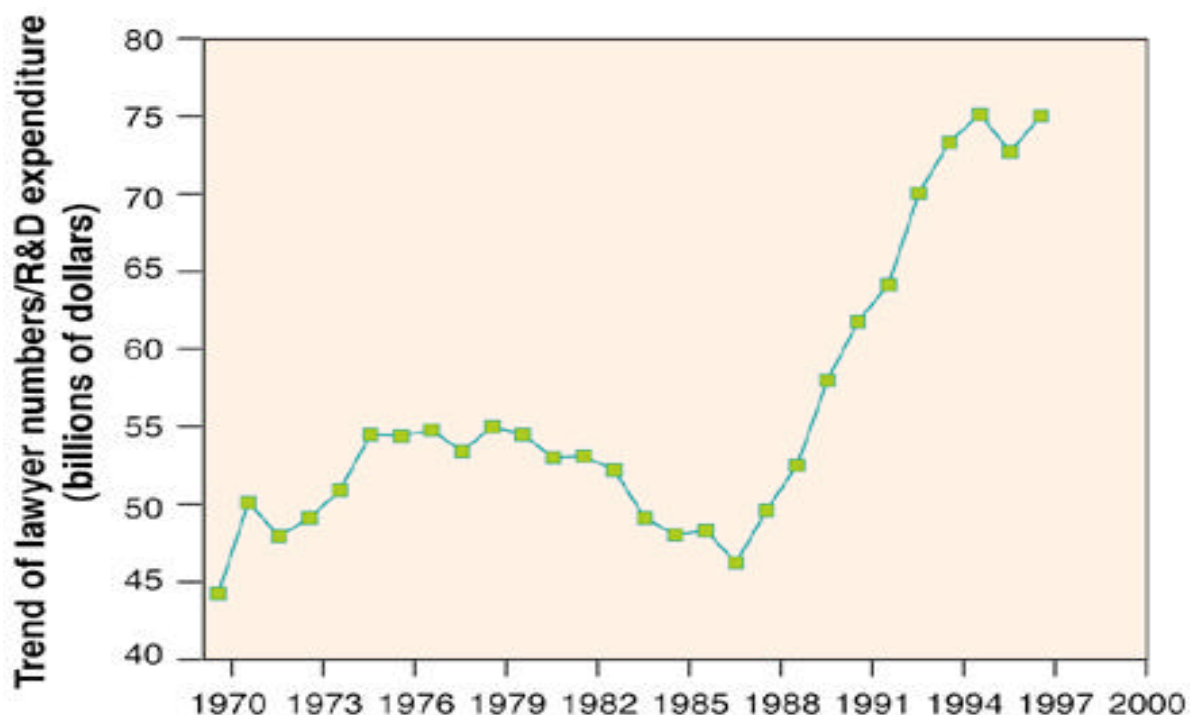
As shown, the Bank has long been a conduit for both technology transfer and capacity building in agriculture, health, energy, transportation, and other sectors. However, notwithstanding the recent improvements, the Bank's support for S&T has been undertaken in an uncoordinated or non-strategic manner; Bank policy toward the sector has not been formulated in an integral or holistic way. The Bank is now reconsidering this approach, and examining whether a more explicit strategy and more focused activities for the support of S&T are warranted. This will lead to a coherent strategy that gives the proper weight to S&T issues within the Bank's overall priorities.

As part of this direct focus on S&T, the Bank is examining the policies and practices that are prerequisites for countries to reap social and economic benefits from their investments in science and technology. In this context, it is important to consider how national strategies for S&T should vary according to particular country circumstances, as well as how the World Bank and other organizations can best contribute to the promotion of S&T capacity.

The role of "global public goods" is likewise essential to any discussion of international S&T cooperation. A critical issue between the developing world and the wealthy, scientifically advanced countries is whether and to what extent discoveries of global significance—such as knowledge that could lead to less expensive AIDS medications or the protection of crops using environmentally safe, natural alternatives to chemical insecticides—can and should be made available in the global public domain. Serious and consequential decisions surround the balance between, on the one hand, ethical and humanitarian obligations to make the most effective treatments and solutions

available to those in need and, on the other hand, protecting the system of incentives [principally intellectual property protection] which allows such solutions to be developed in the first place.

### **Trends in Intellectual Property Lawyers<sup>15</sup>**



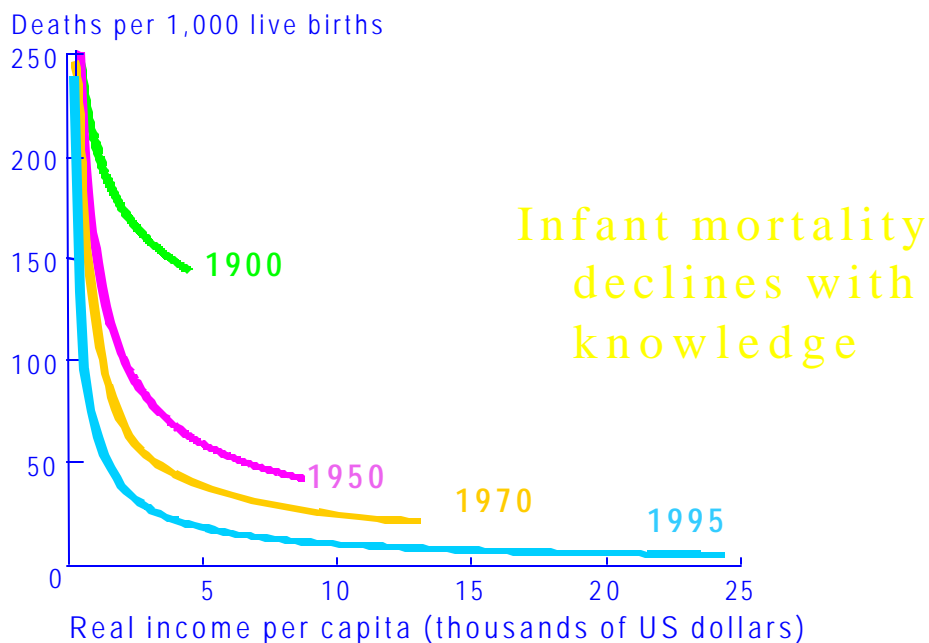
### **Building S&T Capacity is an Essential Part of Comprehensive Development.**

Science contributes to development, but countries need a certain level of capacity in order to reap the benefits of S&T. Countries that lack this capacity will suffer greater consequences as the frontiers of science and technology advance. Lagging countries will not only miss out on new benefits (rising life expectancy, lower infant mortality, improved health, nutrition, and sanitation, etc.), they will be increasingly vulnerable to emerging threats. This is already occurring. Consider the predicament of poor countries with high HIV infection rates. They can afford neither to develop their own solutions nor to buy existing remedies from the developed world. Gains in life expectancy achieved over the past forty years are, in some cases, being reversed. Similarly, the poor—who are disproportionately vulnerable to the effects of climate change and natural disasters—stand to benefit most from better use of emerging technological know-how in areas such as meteorology and remote sensing. New knowledge and technology make possible greatly improved forecasting and early warning techniques that can drastically mitigate the effects of both natural disasters [e.g., Hurricane Mitch which devastated Central America, or the recent catastrophic flooding in coastal Venezuela, Mozambique, India and Bangladesh] and land and environmental degradation. Other new technologies can be used to improve agricultural production and distribution (lowering the proportion of food that is wasted due to poor distribution systems), to make exports more competitive

<sup>15</sup> J. A. Barton, *Science* 287: 1933-34 (2000)

through better metrology, standards, testing, and quality (MSTQ) or to improve quality and availability of health care services, to name just a few of the possible examples. Yet another important advantage of improved S&T capacity will be its role in informed public policy choices, which increasingly require scientific literacy.

### **Knowledge makes the Difference between Sickness and Health**



Elements of a strong S&T system include, *inter alia*, good basic science education, sound higher education management, adequate intellectual property rights protection, governmental technical competency for research priority setting, functioning financial (especially venture capital) markets, and modern information and communications infrastructure.

**Knowledge is transformed into goods and services through a country's National Innovation System.** Knowledge by itself does not transform economies. Nor are positive returns to investments in R&D or other knowledge inputs guaranteed. Examples can easily be found of countries that invested heavily in S&T capacity without gaining any significant returns on their efforts. This is because the benefits of scientific and technological knowledge appear when it is employed within a complex system of institutions and practices that has come to be known as a National Innovation System (NIS). An NIS is a web of: (i) knowledge-producing organizations in the education and training system (such as universities and research institutes); (ii) the macroeconomic and regulatory framework, including trade policies that affect technology diffusion; (iii) innovative firms and networks of enterprises, and the knowledge generation that

accompanies the production of goods and services; (iv) communications infrastructures; and (v) selected other factors, such as access to the global knowledge base or certain market conditions that favor innovations. An NIS is effective to the extent that these elements are developed and work in harmony to bring forth new products and processes that have economic and social value.

The Bank recognizes that making lopsided or unbalanced investments (for example, in prestige science to the neglect of technology development) can be as fruitless as doing nothing, and more expensive. It is with this in mind that we are currently analyzing the idiosyncrasies of various S&T-related practices, as well as how they should be sequenced and balanced. This analysis breaks down into four main subcategories.

**The Enabling Environment**—starting from the most “macro” or generic considerations (low inflation, openness of trading regimes, policies toward foreign investment, and the quality and maturity of the banking system) and moving toward the more specific (the role of intellectual property rights protection, competitiveness and general private enterprise policies, incentives to acquire and adapt technology, the public sector’s role in metrology and standard setting, and taxation policies).

**Firm-level Considerations**—involving the ability of enterprises to “deepen” the use of technology. This often involves moving from use of rudimentary technologies to consulting for engineering services, from licensing to adaptation, or from basic design methodology to creation of products and processes that are fundamentally new to the world. It may be useful to provide temporary incentives to undertake R&D (e.g., initial subsidies for contract research with universities, engineering consulting services, matching grant programs for R&D, “scientist-in-industry” programs, student internships with firms and other forms of university-industry collaboration), in order to solve the information problems that perpetuate a culture in which businesses, as potential knowledge users, remain isolated from the knowledge creators and adapters.

While policy environments and supporting institutions will always remain crucial to successful S&T development efforts, business enterprises are the fundamental actors in the technological innovations that turn benefits from science and technology into reality. It is the Bank’s position that progress in use of technology by firms is the *sine qua non* for reaping the benefits of science and technology.

**Public Role in Support of S&T:** A key question under consideration is the proper role for public action in the promotion of S&T. National governments must decide: (i) what they hope to gain from the S&T sector; (ii) the amount of resources they are willing and able to devote to obtain these results; and (iii) the ways in which public involvement with S&T will be managed and administered. The main questions involve how to create a portfolio of S&T investments that meets diverse needs—both horizontal (across health, environmental, energy, infrastructure, and other sectors) and vertical (striking a balance between upstream or fundamental research and downstream or applied work). Also critical here is the public role of science in governance, especially through procedures such as use of anonymous peer review for allocation decisions.

An integral part of the public role for S&T is the way in which governments define, identify, promote, and protect S&T-related public goods. A central issue is the balance between private interests and the concomitant incentives to innovate versus legitimate social goals that require knowledge, information, products, and processes to be publicly available through means other than markets. An important issue within the public goods discussion is the government's role in the establishment, regulation, and maintenance of an appropriate information and communications infrastructure. This concern is linked to other World Bank initiatives that deal more generally with the consequences of the "Digital Divide."

The many challenges for developing countries in S&T-related public policy issues range from assuring the minimum level of public understanding of science necessary for informed civic decisions, to creating channels for appropriate advice on scientific issues in legislation and governance, to negotiation of and compliance with international treaties involving scientific and technological issues.

**Building and Maintaining Human Capital:** Critical among the public sector's responsibilities are those which involve the development of human capital. Appropriate policy will take into account the dynamics of knowledge production systems, from basic education through higher education to the creation of knowledge in private sector laboratories by highly trained specialists.<sup>16</sup> Clearly of concern is the role of science in basic education, and the preparation of young people prior to reaching university age. Also essential to human development is the complex nexus of institutions and actors that make up national higher education systems. These are usually the locus of a country's main efforts in knowledge production and human capital training in S&T. From the viewpoint of S&T, numerous issues relate to the strength and adequacy of the system. [An excellent summary of these issues is contained in the report recently-published by an independent Task Force, co-sponsored by the World Bank and UNESCO, "Higher Education in Developing Countries: Peril and Promise."]

Development based on S&T capacity relies heavily on both the adequacy of engineering education--and, more generally, the science-based professions such as computer science, agronomy, and certain aspects of nutrition and human health, which may not be associated with the advanced university degrees or research systems--and on the quality of graduate (especially doctoral) education and training. The overall public support system for R&D and S&T is therefore vital. Adequacy and efficiency of funding systems, use of peer review, means of funding graduate students and average length of graduate study are some of the directly linked concerns. Also worthy of consideration are the government's role as a consumer (as opposed to a funder or performer) of research, the diversity of the research portfolio and its match to national needs, balance of long- and short-term research, as well as basic and applied, and the stimulation of partnerships among government, industry, and academia.

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<sup>16</sup> This discussion focuses primarily on training and production of knowledge as a public good (i.e., educational and not-for-profit research institutions). Because, however, in advanced economies, greater percentages of investment are made by the private sector and greater amounts of knowledge are created within wholly private, for-profit concerns, the Bank is largely concerned with how knowledge production moves from universities and other research institutions to firms . .

Some of the new challenges facing universities include balancing the positive aspects of private partnerships [revenue generation, proximity to end-users, conduits for students into labor markets] with conflict of interest issues that arise from contract research and/or ownership of equity in the commercialization of research finding. Effective university management requires the ability to deal with questions of distributing public support for research within budget constraints; allocation procedures; competition, transparency, and peer review; research evaluation and accountability for results; special programs and national priorities. Likewise, public, non-university research institutes face important management issues, especially from the point of view of vertical integration of research and connections across different purposes and disciplines. All S&T systems, even (some would say especially) the most successful, are constantly changing and seeking to adapt to new challenges, threats, and opportunities.

**National Strategies and the Role of the World Bank and the International Community:** The Bank and its partners are challenged to provide policy advice on what governments can do to promote the maximum contributions of science and technology to development, given the variety of individual circumstances in which they find themselves. We must necessarily focus on how policies should vary according to specific country characteristics, such as size or population, level of economic development, and/or existing capacity and previous tradition in science and technology. The Bank is also considering S&T issues from a regional perspective, as well as the issue of “tailoring” the S&T endeavor to the specific needs of a given country.

A number of issues in S&T are of particular concern to countries as they seek to improve their research systems. Two such issues are: (i) Brain Drain, and ways to counterbalance the migration of talented and highly skilled people in an increasingly globalized market for human capital<sup>17</sup>, especially as rich countries continue their efforts to lure the best and brightest to jobs in the developed world; and (ii) combining excellence and relevance in science research, and avoiding the tendency to define, fund, and recognize as excellent only those research topics that are of concern to rich nations, and dominate prestigious international journals.

We must continually seek to enhance the role of the international S&T community (of both scientists/researchers and multi- and bi-lateral donors, including the World Bank). Research is now being done to estimate the size and impact of bilateral funding on researchers in the developing world<sup>18</sup>. The Bank is also examining different conceptions of support for centers of excellence in the developed and developing worlds, and different models for providing support to outstanding researchers, in order to identify

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<sup>17</sup> see, e.g., United States Public Law No. 106-313. "American Competitiveness in the Twenty-first Century Act of 2000."

<sup>18</sup> see, e.g., Reaching Out: Canada, International Science and Technology, and the Knowledge-based Economy. Report of the Expert Panel on Canada's Role in International Science and Technology.

Presented to The Prime Minister's Advisory Council on Science and Technology, June 23, 2000.

the aspects of successful programs that have succeeded (or have the potential to succeed) in a variety of developing country settings.

In its effort to develop a clear science and technology policy strategy, the Bank has been mindful of many considerations: what changes should be made to country dialogue and lending; how to improve cooperation and knowledge management among staff who works on science and technology issues; the effectiveness of existing mechanisms (including staffing and recruitment issues) for adjusting to the changes to the Bank's work that are necessarily brought about by scientific and technological change; and how the Bank should work with the international S&T community and multi- and bi-lateral partners (based on both the comparative advantage of different partners and the lessons of previous experience in promoting S&T).

## **Towards Innovative Action: the Millennium Science Initiative**

In parallel with the development of a comprehensive science and technology strategy, the Bank is seeking to stimulate greater operational collaboration with client countries for improvement of S&T capacity. To make this possible, a number of innovative actions are planned and others underway. These include projects undertaken under the aegis of the Millennium Science Initiative (MSI). The MSI is not a new initiative per se: it makes use of the Bank's existing lending instruments, but strongly emphasizes the need for countries to improve the performance of their science and technology systems. To date, three clients are participating in the MSI. Chile and Venezuela have taken Learning and Innovation Loans to fund MSI projects, and Mexico has adapted a previously existing S&T loan to include an MSI pilot. Discussions are underway in Brazil, Thailand, and Romania for additional projects or project components. In addition, the Bank is working with partners from the international science community to find ways to make the MSI an effective option for science in Sub Saharan Africa.

Simply stated, the MSI is lending designed to support projects that award large multi-year research grants to top researchers, through a transparent and highly selective competition. The grants normally fund institutes that function as centers of excellence in their domains; the grants do not fund physical infrastructure or buildings, and are made for a fixed time period. Projects are generally peer-reviewed by top international peers and a committee of recognized stature does selection. Grant amounts are at or close to international standards for the given disciplines, and principal investigators are given wide autonomy on how to spend grants. All funded projects include substantial human resources training and international connections.

The basic idea behind MSI projects is to stimulate a part of the national S&T system to function according to international best practice for research funding. The belief is that if these practices are followed, the quality and cost-effectiveness of research performed in the developing world could more closely resemble that of rich countries. The rationale for these principles is well understood within the world S&T community:

- Cutting-edge research is an essential part of an effective National Innovation System.
- Science and technology are intertwined.
- Trained human brains are the most effective knowledge transfer and adaptation mechanism.
- Good science is international.
- Anonymous peer review and competitive funding facilitate quality and productivity in science and technology.

It is anticipated that the MSI will become an umbrella for new lending, through which the Bank's client countries can borrow to improve their scientific and technological capacity. Projects that fall under the aegis of the MSI will generally take the form of highly selective competitive funds to support research. These funds will differ according to a country's specific needs and circumstances, but they share a few essential characteristics. All MSI projects will provide targeted support that focuses on (i) research excellence; (ii) human resources training; and (iii) linkages to partners in the international science community and in the private sector.

MSI projects—although they vary according to individual country circumstances—will conform to the following basic structure:

- Resources contributed to a competitive fund to support research, situated within some part of the participating country's national research system;
- Rules for the competitive allocation of these resources, through a selection committee composed of distinguished researchers of international stature;
- A light administrative structure that assists with logistics of the recipient selection process and the implementation of the research grants;
- A Board of Directors that oversees the process and approves policy for the MSI.

While the amount awarded will vary, MSI projects will usually follow a two-tiered system. In the first tier, a very small number of truly international-level groups are selected for longer-term funding (5-7 years or longer). In a second tier, promising groups, often composed of younger investigators, are awarded shorter (3-5 year) grants that may be renewable. MSI funding is also used for specific international networking activities that may be outside the grant process.

Many direct and indirect benefits are expected to result from MSI projects. Some of these include:

- A model for the transparent, merit-based allocation procedures that forge "cultures of quality"
- Increased training opportunities for young people, and reduction of "brain drain"
- Global and regional networking with other researchers

## **Progressing With Our Partners**

The Bank is, and will remain, actively engaged in efforts to further enhance the contributions of S&T to the sustainable social and economic development of its client countries. The Bank's approach toward lending for S&T thus far has been relatively uncoordinated and non-strategic, limiting its overall effectiveness. The collaborative formation of a comprehensive strategy for S&T lending arose from the Bank's recognition of the limitations of its previous approach. The strategy, informed by a rigorous consultation process, is compatible with the accelerating importance of knowledge for development. Cutting across sectors, the strategy will stress the interconnections among knowledge assimilation and use, human capacity, and the government roles of setting a proper framework and providing needed public knowledge goods.

While the Bank is undertaking to coordinate its work in the S&T arena, it is simultaneously experimenting with innovative actions to stimulate and refocus efforts to improve the scientific and technological capabilities of its borrowers. The Millennium Science Initiative is going forward in parallel with the development of the S&T strategy so that lessons from its implementation can be incorporated into the strategy. The first two operations under the MSI, for Chile and Venezuela, are Learning and Innovation Loans, and lessons from their implementation, will be incorporated into future MSI projects and the strategy. Likewise, the finding of the strategy will have implications for the MSI and the other options the Bank has for supporting improved S&T capacity. As these activities go forward, each will provide complementary lessons to the others